SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, TAKU AMADA, a citizen
of Japan residing at Kanagawa, Japan and NAOKI
MIYATAKE, a citizen of Japan residing at Kanagawa,
Japan have invented certain new and useful
improvements in

MULTI-BEAM SCANNING DEVICE

of which the following is a specification:-

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a multi-beam
scanning device used in a laser writing optical system
5   of an image formation apparatus, such as a color laser
printer, a digital copier, or the like.

2. Description of the Related Art

In a multi-beam scanning device which uses two
10   semiconductor laser arrays as light sources, a method
for adjusting the sub-scanning beam pitch on a to-be-
scanned body such as a photoconductor drum, is proposed
by Japanese laid-open patent application No. 2000-75227,
as an example of adjusting the sub-scanning beam pitch
15   on a to-be-scanned body such as a photoconductor drum.

According to the above-mentioned publication,
a light source unit is provided which includes a holding
member which holds integrally two semiconductor laser
arrays together with two coupling lenses, and, the sub-
20   scanning beam pitch on a to-be-scanned body is adjusted
as this light source unit is rotated about a rotation
axis which corresponds to the optical axis of the
optical system.

Moreover, according to the same publication,
25   even in a case of a type in which beams emitted from the

two semiconductor laser arrays are combined by utilizing
polarization characteristic of the laser, the above-
mentioned method can also be applied for precisely
adjusting the sub-scanning pitch on the to-be-scanned
5 surface.

However, according to the above-mentioned art,
there is a possibility that the main scanning beam pitch
is also changed due to the rotation of the light source
unit, and, also, when the mounting precision of the
10 scanning optical system or the mounting precision of the
light source unit may not be sufficiently secured, the
state of the beam arrangement before the adjustment is
not satisfactory one, and, as a result, there is a
possibility that the predetermined value on the sub-
15 scanning beam pitch cannot be obtained only by the
rotation of the light source unit.

Therefore, when an electrostatic latent image
is formed on a photoconductor drum through the multi-
beam scanning device having such a light source unit,
20 and then, a toner image is obtained from the latent
image through a well-known development and fixing
processes, the thus-obtained final image may be degraded
such as fluctuation on vertical lines or the like, due
to the change in the main scanning beam pitch after the
25 sub-scanning beam pitch adjustment and/or insufficient

state of beam arrangement before the sub-scanning beam pitch adjustment.

SUMMARY OF THE INVENTION

5   The present invention has been devised in order to solve these problems, and an object of the present invention is to provide a multi-beam scanning device by which a satisfactory final image can be obtained in an image formation apparatus employing this

10   scanning device even after the sub-scanning beam pitch adjustment has been made.

A multi-beam scanning device according to the present invention, scanning a to-be-scanned surface with a plurality of laser beams simultaneously, comprises:

15   a light-source unit comprising a plurality of laser arrays, each comprising a plurality of light-emitting points, a corresponding plurality of coupling lenses coupling laser beams emitted from the plurality of laser arrays, and a holding member integrally holding

20   the plurality of laser arrays and plurality of coupling lenses rotatably approximately about optical axes on the laser beams; and

a scanning optical system deflecting the laser beams emitted from the light-source unit and imaging

25   them onto the to-be-scanned surface.

There, the light-source unit and scanning optical system are configured so that the following equation be satisfied:

5

$$AY = |q \times \cos \phi \times mY \times (n-1) / (2 \times fcol \times \tan \theta \times \cos \gamma \times mZ)| \leq 0.1$$

where:

n denotes the number of light-emitting points
10 on each LD array;

q denotes an interval between each adjacent ones of the light-emitting points;

ϕ denotes an inclination angle of each laser array with respect to a sub-scanning direction;

15 mY denotes a magnification of the scanning optical system on main scanning direction;

mZ denotes a magnification of the scanning optical system on sub-scanning direction;

fcol denotes the focal length of each coupling
20 lens;

θ denotes half a crossing angle at which the laser beams emitted from the plurality of laser arrays cross therebetween;

γ denotes a maximum required rotational angle
25 of the light-source unit in case of adjustment.

Further or alternatively, in the multi-beam scanning device, the light-source unit and scanning optical system are configured so that the following equation be satisfied:

5

$$AZ = |q \times sine\ \phi \times (n-1)/(2 \times fcol \times \tan \theta \times \cos \gamma)| \leq 0.1$$

Thereby, even in case, an error in scanning
10   line interval occurring due to optical-axis manufacture/assembling error or so between the plurality of laser arrays should be corrected by rotating (γ rotation) the holding unit in an adjustment work, a newly occurring scanning line interval error along the
15   sub-scanning direction and/or beam spot interval error along the main scanning direction due to the above-mentioned adjustment work can be controlled to be made within a permissible range

A multi-beam scanning device according to
20   another aspect of the present invention, scanning a to-be-scanned surface with a plurality of laser beams simultaneously, comprises:

a light-source unit comprising a plurality of laser arrays, each comprising a plurality of light-
25   emitting points, a corresponding plurality of coupling

lenses coupling laser beams emitted from the plurality

of laser arrays, and a holding member integrally holding

the plurality of laser arrays and plurality of coupling

lenses rotatably approximately about optical axes on the

5   laser beams;

a scanning optical system deflecting the laser

beams emitted from the light-source unit and imaging

them onto the to-be-scanned surface; and

a part switching a scanning density on the to-

10   be-scanned surface by rotating the light-source unit

approximately about the optical axes on the laser beams

emitted therefrom.

Thereby, even with a simple arrangement, it is

possible to easily perform switching of the scanning

15   density on the to-be-scanned surface in the multi-beam

scanning device employing the plurality of laser arrays

by appropriately rotating (γ rotation) the holding

member integrally holding these laser arrays.

Further, it is preferably that the light-

20   source unit and scanning optical system are configured

so that the following formula be satisfied:

$$\Delta RY = \left| \{(n-1) \times (2n-1)/2\} \times \{(q \times \cos\phi \times mY \times d)/(fcol \times \tan\theta \times mZ)\} \right| \leq d/4$$

where:

d denotes scanning line interval;

n denotes the number of light-emitting points on each laser array;

5   q denotes an interval between each adjacent ones of the light-emitting points;

ϕ denotes an inclination angle of each laser array with respect to a sub-scanning direction;

mY denotes a magnification of the scanning

10   optical system on main scanning direction;

mZ denotes a magnification of the scanning optical system on sub-scanning direction;

fcol denotes the focal length of each coupling lens;

15   θ denotes half a crossing angle at which the laser beams emitted from the plurality of laser arrays cross therebetween;

ΔRY denotes the main-scanning-directional component of beam-spot interval between both ends of

20   beam spots on the to-be-scanned surface from each laser array.

Further or alternatively, it is preferable that the light-source unit and scanning optical system are configured so that the following formula be

25   satisfied:

$$\Delta RZ = \left|\{(n-1)\times(2n-1)/2\}\times \right.$$

$$\left.\{(q \times \sin\phi \times d)/(fcol \times \tan\theta)\}\right| \leq d/4$$

where ΔRZ denotes the sub-scanning-directional component of beam-spot interval between both ends of beam spots on the to-be-scanned surface from each laser array.

Thereby, it is possible to control within a predetermined range the beam spot interval error on the to-be-scanned surface occurring due to the γ rotation of the holding member for the switching of the scanning density on the to-be-scanned surface.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and further features of the present invention will become more apparent from the following detailed description when read in conjunction with the following accompanying drawings:

FIG. 1 illustrates a multi-beam scanning device in a first embodiment of the present invention;

FIG. 2 shows a perspective view of parts/components located in and near a light source unit in the configuration shown in FIG. 1;

FIG. 3 shows a perspective view of an LD base shown in FIG. 2 viewed from the rear side;

FIG. 4 illustrates a state of crossing of

laser beams on a deflection reflective surface of a polygon mirror in the configuration shown in FIG. 1;

FIGS. 5A and 5B illustrate a state where an LD array is inclined with respect to a sub-scanning

5 direction in the configuration shown in FIG. 1;

FIGS. 6, 7 and 8 illustrate adjustment of a beam spot arrangement on the to-be-scanned surface in the configuration shown in FIG. 1;

FIGS. 9A, 9B, 9C, 10A, 10B and 10C illustrate

10 how to derive conditional formulas according to the present invention on the configuration shown in FIG. 1;

FIGS. 11 and 12 illustrate different examples in adjustment of beam spot arrangement according to the first embodiment of the present invention;

15 FIGS. 13A, 13B and 14 illustrate how to derive conditional formulas according to the present invention on the configuration shown in FIG. 1;

FIGS. 15A and 15B illustrate a configuration of a comparison example for the first embodiment of the

20 present invention;

FIGS. 16A and 16B illustrate an arrangement on an LD array and an arrangement on a to-be-scanned surface in the configuration shown in FIGS. 15A and 15B;

FIGS. 17 and 18 illustrate a light-source unit

25 according to a second embodiment of the present

invention (FIG. 17 shows a main scanning section while FIG. 18 shows a sub-scanning section);

FIG. 19 shows a conceptual perspective view of a multi-beam scanning device according to a third
5 embodiment of the present invention;

FIGS. 20A and 20B illustrate exploded perspective views of a holding mechanism for LD array and a light-source rotating mechanism, applicable to the third embodiment of the present invention;

10 FIG. 21 shows a perspective view of another configuration example of a light-source device applicable to the third embodiment;

FIGS. 22A and 22B illustrate an arrangement angle (inclination angle) of light-emitting points on an
15 LD array with respect to a sub-scanning direction(A), and the same of beam spots on a to-be-scanned surface (B) in the third embodiment;

FIGS. 23A and 23B illustrate a scanning density switching operation through γ rotation according
20 to the third embodiment of the present invention;

FIG. 24 illustrates change in beam spot arrangement on the to-be-scanned surface occurring due to the γ rotation of the light-source device (light-source unit) in the configuration of the third
25 embodiment;

FIG. 25 shows a specification of the third embodiment of the present invention;

FIG. 26 show s a specification of a fourth embodiment of the present invention; and

5   FIGS. 27A, 27B, 27C and 27D illustrate configuration examples of image formation apparatuses each applying any one of the embodiments of the present invention.

10   DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates a general configuration of a multi-beam scanning device in a first embodiment of the present invention, FIG. 2 shows a perspective view of a part including a light source unit of this device, and FIG. 3 shows a perspective view of FIG. 2 viewed

15   from the reverse side. This multi-beam scanning device 1 is provided in a color laser printer, and has a function of scanning on a surface (to-be-scanned surface) 16a of a photoconductor 16 of the color laser

20   printer with laser beams, thereby, according to a well-known electrostatic photographic scheme, an electrostatic latent image being formed on the photoconductor surface.

As shown in FIG. 1, in the multi-beam scanning

25   device 1, two semiconductor laser arrays (referred to as

LD arrays, hereinafter) 11a and 11b each of which

includes a plurality of light emitting points 10 (see

FIG. 5) disposed like an array with uniform intervals,

two coupling lenses 12a and 12b for carrying out

5   coupling of the light emitted from the LD arrays 11a and

11b, respectively, a cylindrical lens 13 for making the

laser beams from the coupling lenses 12a and 12b be

imaged as long images along the main scanning direction

on a deflection reflective surface 14a of a polygon

10   mirror 14, a scanning optical system 15 for making the

to-be-scanned surface 16a which is the surface of the

photoconductor drum 16 to be scanned at a uniform

velocity with beam spots imaged from the laser beams

deflected/reflected by the polygon mirror 14, and the

15   polygon mirror 14 for deflecting the laser beams. It is

noted that, although FIG. 1 shows the scanning optical

system 15 as a simplified symbol, this actually consists

of a predetermined combination of lenses and mirrors, as

well-known in the art (see FIG. 19, 'scanning optical

20   system 115, as a configuration example).

As shown in FIG. 2, the two LD arrays 11a and

11b are held on a common LD base (holding member) 21,

and the corresponding coupling lenses 12a and 12b are

fixed at a receptacle part of the LD base 21 after

25   having undergone positional adjustment such as to be

suitable to the collimate property of the light beams and the directions of the optical axes thereon according to the characteristics of the subsequent scanning optical system 15. According to the first embodiment, a

5   light source unit 18 includes the LD arrays 11a and 11b, the coupling lenses 12a and 12b, and the LD base 21.

This light source unit 18 is held on an insertion hole 32 provided in an optical housing 31 in a manner such that it can be rotated approximately about

10   the optical axes on the laser beam. By this rotation of the light source unit 18 approximately about the optical axes, thereby, a distance PZ between centers of the beam spots of the respective LD array 11a or 11b (pitch between centers; the sub-scanning directional component

15   of the distance between Ca and Cb shown in FIG. 8) can be adjusted, as will be described later. Moreover, at least one of the LD arrays 11a and 11b is rotatably held on the LD base 21 approximately about the optical axes.

20   It is noted that, the above-mentioned 'rotation approximately about the optical axes', referred to as a 'γ rotation', means a rotation of the light-source unit (light-source device) about an axis which passes through the central position of the light-

25   emitting points of the LD arrays 11a and 11b, and

extends in parallel to the optical axes of these LD arrays.

As shown in FIG. 3, the LD array 11a is fixed to the LD base 21 with screws 25 using a pressing plate

5   22. In case it is fixed, a cut-out 24 provided in a package of the LD array 11a is engaged with a projection 23 provided in the pressing plate 22, and, then, as a result of the pressing plate 22 being rotated with respect to the base 21, it can be rotationally adjusted.

10   Similarly, the LD array 11b is fixed onto the base 21 with a pressing plate 22 together with screws 25 and can be rotationally adjusted.

By configuring the light source unit 18 as described above, it is possible to correct an beam pitch

15   arrangement error on the light-emitting points on the LD array 11a (or 11b) by rotation of the LD array by itself alone approximately about the optical axis thereof.

According to the first embodiment, as shown in FIG. 5, the n light-emitting points (n=4, in the

20   example) are disposed with equal intervals in each LD array, and it is called n-ch LD array, and, as will be described now, a beam-spot arrangement made on the to-be-scanned surface 16a made by the 2n light beams emitted from these two LD arrays 11a and 11b is adjusted,

25   as will be described with reference to FIGS. 4 through

14.

    As shown in FIG. 1, the laser beams emitted
from the LD arrays 11a and 11b are coupled by the
corresponding coupling lenses 12a and 12b, respectively,
 5 and then, are shaped by apertures (not shown in the
figure). These laser beams are imaged to be line images
long along the main scanning direction (imaged along the
sub-scanning direction) on the deflection reflective
surface 14a of the polygon mirror 14 through the
10 cylindrical lens 13. Then, after the deflection and
reflection is carried out thereby, they make beam spots
on the to-be-scanned surface 16a of the photoconductor
drum 16 through the scanning optical system 15, and
thereby, scanning on the to-be-scanned surface 16a at a
15 uniform velocity can be achieved.

    In this configuration, as variation in
reflection point between respective laser beams can be
controlled as a result of the optical axes of the laser
beams coming from the two semiconductor laser arrays
20 being made to cross near the deflection reflective
surface 14a, and, thus, it is possible to effectively
control the deviation in the beam characteristics on the
to-be-scanned surface.

    As shown in FIG. 4, the two LD arrays 11a and
25 11b are disposed away from one another along the main

scanning direction, the laser beams (namely, the optical axes of the LD arrays 11a and 11b) coupled by the coupling lenses 12a and 12b, respectively, cross mutually near the deflection reflective surface 14a of

5 the polygon mirror 14, and the crossing angle is set as 2θ, as shown in FIG. 4.

Generally, the LD array 11a (having the intervals q between adjacent light emitting points) is disposed to have an inclination angle ϕ with respect to

10 the sub-scanning direction (vertical direction on the figure) as shown in FIG. 5A. In this case, on the to-be-scanned surface 16a, as shown in FIG. 6, as a result of being magnified by magnification (mY along the main scanning direction and mZ along the sub-scanning

15 direction) of the optical system, the resulting interval of adjacent beam spots is expressed as QY and QZ on the to-be-scanned surface 16a. Moreover, in FIG. 5B, the light-emitting points on the LD array 11a are expressed as r1, r2, ..., rn, while the beam spots on the to-be-

20 scanned surface 16a corresponding to the above-mentioned light-emitting point are expressed with R1, R2, ..., Rn in FIG. 6, respectively. There, 'n' shows the number of the light-emitting points on each of the LD arrays 11a and 11b.

25 By rotating (rotation angle: γ) the light

source unit 18 approximately about the optical axes, as shown in FIG. 8, the sub-scanning direction component PZ of the distance (pitch between adjacent centers) between center positions Ca and Cb of beam spots from the

5 respective LD arrays 11a and 11b on the to-be-scanned surface 16a can be set to be a predetermined value according to the following formula (1). There, in the formula (1), fcol denotes the focal length of the coupling lens 12a (12b), and mZ denotes the imaging

10 magnification along the sub-scanning direction of the entire optical system (multi-beam scanning device).

$$PZ = 2 \times fcol \times \tan\theta \times \sin\gamma \times mZ \qquad \ldots (1)$$

15 How to derive the above-mentioned formula (1) will now be described with reference to FIGS. 9A-9C and FIGS. 10A-10C. As shown in FIG. 9A, unit vectors of the laser beams coming from the respective LD array 11a and 11b are assumed as a1 and a2 (i.e., directions of the

20 optical axes of the respective LD arrays), respectively, and, also, as shown in FIGS. 9B and 9C, the vectors of the laser beams obtained when the LD arrays 11a and 11b are rotated by an angle γ about the X-axis (γ rotation) is assumed as $\alpha 1$ and $\alpha 2$, respectively. Then, 2 sin θ

25 sine γ is obtained as the sub-scanning component of ($\alpha 1$

- α2). Then, as shown in FIG. 10A, the angle β0 which
is the angle (sub-scanning direction component) between
the laser beams obtained through the γ rotation is
expressed as follows:

5

$$\tan \beta 0 = \sin \theta \sin \gamma / \cos \theta = \tan \theta \sin \gamma$$

Thereby, as shown in FIG. 10B, the scanning
position Z0 on the to-be-scanned surface 16a on the

10 angle β0 between the laser beams is obtained, as
follows:

$$Z0 = fcol \times \tan \theta \times \sin \gamma \times mZ$$

15 Then as shown in FIG. 10C, the formula (1) for
the sub-scanning direction component PZ of the distance
between adjacent centers of the LD arrays 11a and 11b (Z
direction), i.e., the distance between the center
positions Ca and Cb of the beam spots from the

20 respective LD arrays on the to-be-scanned surface 16a
(pitch between centers) is obtained.

In order to arrange the beam spots on the to-
be-scanned surface 16a at equal intervals along the sub-
scanning direction, there are two different methods as

25 shown in FIG. 11 and FIG. 12. According to FIG. 11, the

light-emitting points of the LD array 11a and 11b are arranged alternately. In this case, the distance between the centers Ca and Cb of the respective LD arrays 11a and 11b corresponds to the distance between

5   adjacent scan lines. According to FIG. 12, the light-emitting points of the LD arrays 11a and 11b are arranged in series. In this case, the distance between the centers Ca and Cb corresponds to the intervals of n scan lines.

10   As shown in FIGS. 5A and 5B, in case each LD array is inclined by the angle ϕ, the arrangement of the beam spots on the to-be-scanned surface 16a along the main and sub-scanning directions, i.e., the interval QY along the main scanning direction and the interval QZ

15   along the sub-scanning direction between adjacent beam spots on the LD array 11a are expressed by the following formulas (4) and (5), respectively. From the following formula (4) and formula (5), the maximum interval on single scan (interval between the beam spots R1 and Rn

20   shown in FIG. 6) is expressed by $(n-1) \times QY$ and $(n-1) \times QZ$, respectively.

        Main scanning direction:

            $QY = q \times \sin \phi \times mY$ ... (4)

25

Sub-scanning direction:

$$QZ = q \times \cos \phi \times mZ \quad ... \quad (5)$$

How to derive these formulas (4) and formula
(5) will now be described based on FIGS. 13A and 13B.
In case the LD array 11a in the state shown in FIG. 13A
is inclined by the angle ϕ as shown in FIG. 13B, the
interval between the light-emitting points on the LD
array 11a is obtained as $qY = q \sin \phi$ along the main
scanning direction while the interval along the sub-
scanning direction is obtained as $qZ = q \cos \phi$. Thereby,
the formula (4) for the interval QY along the main
scanning direction between beam spots on the to-be-
scanned surface 16a (image surface) and the formula (5)
for the interval QZ along the sub-scanning direction are
obtained.

Moreover, an amount of deviation ΔQY on QY
along the main scanning direction of the above-mentioned
beam spot arrangement when the arrangement angle ϕ
changes by slight amount $\Delta \phi$, and an amount of deviation
ΔQZ on QZ along the sub-scanning direction in the same
case are shown by the following formula (6) and the
formula (7). There, the amount of deviation ΔQY along
the main scanning direction is obtained by
differentiating the above-mentioned formula (4) with

respect to ϕ, while the amount of deviation ΔQZ along the sub-scanning direction can be obtained by differentiating the above-mentioned formula (5) with respect to ϕ.

Main scanning direction:

$$\Delta QY = q \times \cos \phi \times mY \times \Delta\phi \quad \dots (6)$$

Sub-scanning direction:

$$\Delta QZ = -q \times \sin \phi \times mZ \times \Delta\phi \quad \dots (7)$$

Furthermore, an amount of deviation ΔPZ on the sub-scanning direction component PZ of the pitch between centers Ca and Cb is expressed by the following formula (10) from the formula (1).

$$\Delta PZ = 2 \times fcol \times \tan \theta \times \cos \gamma \times mZ \quad \dots (10)$$

Position adjustment on the coupling lens 12a (12b) corresponding to the LD array 11a (11b) is made such that a desired collimate characteristic and light-emitting direction (optical axis) may be achieved. Generally, such assembly adjustment is called "optical axis/collimate adjustment". It is assumed that optical axis adjustment accuracy (possible angle error along the

sub-scanning direction on the laser beam) is iZ (rad).

In case the angle errors on the two LD arrays 11a and

11b occur oppositely one another (maximum: 2 × iZ), the

amount E deviation (adjustment error) on the center

5   positions Ca and Cb of the beam spots on the to-be-

scanned surface 16a is obtained, as shown in FIG. 14, by

the following formula (2):

$$E = 2 \times fcol \times \tan(iZ) \times mZ \quad \ldots (2)$$

10

The rotation angle γE of the light source unit

18 required to correct this amount E of derivation

(maximum possible error) is obtained by the following

formula (3) from the formula (1).

15

$$\mathrm{Sin}\ \gamma E = \tan(iZ)/\tan \theta \quad \ldots (3)$$

By rotating the light source unit 18 by the

above-mentioned angle γE, the LD arrays 11a and 11b

20   revolve by the angle γE (relative positional change) and

also each rotates by the same angle alone. Accordingly,

as the change amount on the arrangement angle of the LD

array 11a (11b) alone occurring thereby can be expressed

by $\Delta \phi = \gamma E$. Thereby, as the deviation amount E on the

25   center positions is corrected, the amount of change ΔQY

along the main scanning direction of the beam spot

arrangement and the amount of change ΔQZ along the sub-

scanning direction of the same occurring thereby can be

expressed by the following formulas (8) and (9) from the

5   formulas (6) and (7):

Main scanning direction:

$$\Delta QY = q \times \cos \phi \times mY \times \gamma E \quad \ldots (8)$$

10   Sub-scanning direction:

$$\Delta QZ = -q \times \sin \phi \times mZ \times \gamma E \quad \ldots (9)$$

With reference to FIGS. 15A, 15B, 16A and 16B,

previously, a reason why, in an 8 beam scanning device

15   in which laser beams emitted by two semiconductor laser

arrays 51a and 51b each of which has four light-emitting

points are used, beam spot arrangement on a to-be-

scanned surface 56a is difficult, will now be described

for a comparison example shown in the figures. A

20   configuration of an optical system of the comparison

example shown in the figures is almost the same as that

shown in the figures with which how to derive the above-

mentioned formulas has been described above. However,

as shown FIG. 15B, a light source unit 58 is used there

25   in which beams are combined by using a beam combining

prism 57. Further, coupling lenses 52a and 52b, a cylindrical lens 53, and a scanning optical system 55 are provided there.

As shown in FIG. 15B, in the light source unit

5 58, the LD arrays 51a and 51b are located away from one another along the sub-scanning direction, and laser beams emitted therefrom are combined by the beam combining prism 57 which combines laser beam through a polarization characteristic thereof.

10 The combined laser beams (namely, optical axes of the two LD arrays) cross mutually near the deflection reflective surface of a polygon mirror 54, and the crossing angle is set as 2θ, as shown in the figure. There, in FIG. 15A, the light path on laser beam emitted

15 from the LD array 51a and bent by the beam combining prism 57 is shown in an expanded manner

The specification of the optical system (writing density: 1200 dpi along the sub-scanning direction) of this comparison example is as follows:

20 The interval between adjacent light-emitting points on the LD array 51a (51b): $q = 14$ μm;

The number of light-emitting points on the LD array 51a (51b): $n = 4$;

The arrangement angel of the LD array 51a

25 (51b): $\phi = 0°$;

The focal length of the coupling lens 52a (52b): fcol = 15 (mm);

Half the crossing angle at which the laser beams emitted from the LD arrays 51a and 51b cross near the deflection reflective surface 54a: θ = 0.25°;

The optical axis adjustment accuracy (possible angular error): iZ = 0.6 (mrad);

The imaging magnification on the main scanning direction: mY = 10 (times);

The imaging magnification on the sub-scanning direction: mZ = 3 (times);

The arrangement of light-emitting points at the end of light source (LD arrays 51a and 51b) is shown n FIG. 16A, while the beam spot arrangement on the to-be-scanned surface 56a corresponding thereto is shown in FIG. 16B. In the above-mentioned configuration, the interval QZ along the sub-scanning direction of the beam spots on the LD array 51a (51b) is calculated as 42 μm from the formula (5), and then, the interval of 21 μm (namely, 1200 dpi) can be achieved by arranging alternately the beam spots corresponding to the LD arrays 51a and 51b, as shown in FIG. 16B. There, each scanning-line pitch S which is the interval along the sub-scanning direction of the center positions Ca and Cb of the beam spots between the LD arrays 51a and 51b

(pitch between centers; Ca − Cb) is also 21 μm, and this can be achieved by shifting the positional relationship between the two LD arrays 51a and 51b and the coupling lenses 52a and 52b by 3.5 μm each oppositely along the sub-scanning direction.

Then, when the optical axis derivation iZ = 0.6 (mrad) along the sub-scanning direction occurs due to the positioning accuracy error of LD array 51a (51b) and coupling lens 52a (52b), the pitch Ca − Cb between centers deviates by E= 0.054mm = 54 μm, according to the formula (2). In order to correct this, it is necessary to rotate γE= 0.1375 (rad) = 7.9° the whole light source unit 58, according to the formula (3).

By this rotation, change of ΔQY = 19.3 μm on the interval of adjacent beam spots on each LD array 51a (51b) occurs according to the formula (8) as a result of the thus-occurring angle γE rotation of the LD array 51a (51b) alone occurring thereby.

Thereby, between scans (between the scans of subsequent deflection reflection operations), (n−1) times ΔQY, i.e., 19.3 × (4−1) = 57.9 μm of beam spot arrangement error occurs, and thus, as this value is large, there is a possibility of causing quality degradation on a resulting image by an image formation apparatus employing this scanning device.

As to the sub-scanning direction, since $\Delta QZ = 0$ according to the formula (9) in the case of $\phi = 0°$, then, the formula (5) is applied, and, thus,

5      $$\Delta QZ = q \times (\cos(\phi + \Delta\phi) - \cos\phi) \times mZ = -0.4 \ \mu m$$

since $\Delta\phi = \gamma E = 7.9°$

Therefore, the amount of change of the beam spot interval on both ends of each LD array is 1.2 μm, and is

10   sufficiently small. Thus, no problem occurs concerning the sub-scanning direction.

Thus, according to the above-mentioned comparison example, when the possible positioning error (optical axis deviation along sub-scanning direction)

15   occurs on the LD arrays and coupling lenses, it is difficult to satisfactorily adjust the beam spot arrangement on the to-be-scanned surface 56a. This is because, in order to correct the pitch between centers Ca and Cb (sub-scanning direction) occurring in

20   correcting the above-mentioned positional error, the light source unit 56 should be rotated approximately about the optical axes, and, thereby, the arrangement angle of LD array 51a (51b) necessarily changes. Accordingly, in order to solve this problem, it is

25   necessary to make small as possible the influence on the

beam spot arrangement on the to-be-scanned surface, even

when the arrangement angle of the LD arrays changes as a

result of rotation of the light source unit

approximately about the optical axes (γ rotation).

5   Formulas needed for proving the advantage of

the above-mentioned first embodiment of the present

invention in comparison to the above-mentioned

comparison example will now be described. In the

scanning optical system of the above-mentioned

10 comparison example, change in the beam pitch between

adjacent light-emitting points of each LD array is

expressed by the following formula (11) from the formula

(6), and change (along the sub-scanning direction) in

the pitch between centers Ca and Cb is expressed by the

15 following formula (12) from the formula (10):

$$\Delta QY/\Delta\gamma = q \times \cos \phi \times mY \quad \cdots \quad (11)$$

$$\Delta PZ/\Delta\gamma = 2 \times fcol \times \tan \theta \times \cos \gamma \times mZ \quad \cdots \quad (12)$$

20

          When the value of the formula (11) is fully

small as compared with the value of the formula (12),

the influence of rotation (Δγ) of the light source unit

18 exerted on ΔQZ can also be made sufficiently small.

25 The formula (11) is a formula concerning the arrangement

between adjacent beam spots. With regard to the beam spot arrangement (relation between R1 and Rn in FIG. 6) between the light-emitting points at both ends on each LD array 11a (11b), a formula is obtained as a result of the formula (11) being multiplied by (n-1). Accordingly, the absolute value AY of the ratio of formula (11) × (n-1) and the formula (12) is given by the following formula (13):

$$AY = \left| (\Delta QY/\Delta\gamma) \times (n-1)/(\Delta PZ/\Delta\gamma) \right|$$
$$= \left| (q \times \cos\phi \times mY) \times (n-1)/(2 \times fcol \times \tan\theta \times \cos\gamma \times mZ) \right| \qquad \ldots (13)$$

According to the first embodiment of the present invention, q = 14 μm (light-emitting point interval on each LD array 11a (11b)); n = 4 (the number of light-emitting points on each LD array 11a (11b)), ϕ = 60° (arrangement angle of LD array 11a (11b); fcol = 15 mm (focal length of coupling lens 12a (12b)); θ = 1.5 ° (half the crossing angle of the laser beams emitted from the LD arrays 11a and 11b near the deflection reflective surface 14a; mY = 10 times (imaging magnification on the main scanning direction); mZ = 3 times (imaging magnification on the sub-scanning direction).

In the multi-beam scanning device 1 (writing density: 1200 dpi along the sub-scanning direction) in the first embodiment, the beam spot arrangement on the to-be-scanned surface 16a is such as that shown in FIG. 12, for example. Then, the pitch between centers along the sub-scanning direction should be set as

$$n \times (\text{scan-line interval}) = 4 \times 21 = 84 \ (\mu m)$$

Further, the relative positional shift (along the sub-scanning direction) between the two LD arrays 11a and 11b and the coupling lenses 12a and 12b should be set as 14 μm in the mutual opposite direction. Then, it is assumed that the positional accuracy error between the LD arrays 11a and 11b and the coupling lenses 12a and 12b causes the optical-axis shift along the sub-scanning direction of

$$iZ = 0.6 \ (mrad)$$

In this case, same as in the above-described case of comparison example, from the formula (2), the amount of change of E= 0.054 (mm) occurs in the pitch between centers Ca and Cb along the sub-scanning direction, the rotation angle γE of the light source unit 18 needed for

correcting this change is as follows:

$$\gamma E = 0.023 \text{ (rad)} = 1.3°$$

5   from the formula (3). Then, from the formula (8), the

amount of change ΔQY in the adjacent beam spot interval

occurring due to the rotation of γE on the light source

unit 18 can be controlled as being $\Delta QY = 1.6$ μm, and

thus, the amount of deviation in the beam spot interval

10   between the light-emitting points at both ends can be

controlled as being 4.8 μm.

When the absolute value (AY, see the formula

(13)) of the ratio of "the main scanning direction

component: $\Delta QY \times (n-1)/\Delta\gamma$ of the change in the beam spot

15   interval between the light-emitting points at both ends

in the same LD array 11a (11b)" and "the sub-scanning

direction component: $\Delta PZ/\Delta\gamma$ of the change in the center

positions of the beam spots between the two different LD

arrays 11a and 11b" occurring when rotating the light

20   source unit 18 approximately about the optical axes may

preferably be limited as shown in the following formula

(14), for example, i.e., the coefficient C1 is made not

more than 1/10, it is possible to correct the center-to-

center deviation E caused by the optical-axis adjustment

25   error easily (by the sensitivity of 1/10).

$$AY \leq C1,$$

$$C1 = 0.1$$

$$\cdots \quad (14)$$

5   For example, deviation occurring in the
center-to-center distance up to 100 μm can be corrected
in case the permissible value of the amount of change in
beam spot arrangement along the main scanning direction
is set as 10 μm (≈ 21 (μm) /2), i.e., 1/2 dot in writing
10   density of 1200 dpi, determined according to an image
output experiment result. In other words, even when
such a correction is made on the center-to-center
distance ΔPZ, the change ΔQY in the main-scanning-
direction beam spot arrangement can be controlled to be
15   within the above-mentioned permissible value.

According to the first embodiment of the
present invention, $AY = 0.09$ and thus, the requirement
of formula (14) is satisfied. However, the adjustment
becomes easier as the coefficient C1 on the formula (14)
20   can be smaller. Accordingly, more preferably, $C1 = 0.02$,
for example. In the above-mentioned comparison example,
$AY = 1.07 > 0.1$, the requirement of formula (14) is not
satisfied, and, thus, a problem may occur.

The same study as in the case of the main
25   scanning direction mentioned above will now be made on

the sub-scanning direction. Namely, the absolute value
AZ of the ratio of "the sub-scanning direction
component: $\Delta QZ \times (n-1)/\Delta\gamma$ of the change in the beam spot
interval between the light-emitting points at both ends

5   in the same LD array 11a (11b)" and "the sub-scanning
direction component: $\Delta PZ/\Delta\gamma$ of the amount of change in
the center positions of the beam spots between the two
different LD arrays 11a and 11b" occurring when rotating
the light source unit 18 approximately about the optical

10   axes is expressed by the following formula (15) from the
formula (7) and formula (10):

$$AZ = | (\Delta QZ/\Delta\gamma) \times (n-1)/(\Delta PZ/\Delta\gamma) |$$
$$= | (q \times \sin\phi \times (n-1))/(2 \times f_{col} \times \tan\theta \times \cos\gamma) |$$

15   ... (15)

By controlling this absolute value AZ by
configuring the scanning device 1 such that the
coefficient C2 included in the following formula (16) be

20   not more than 1/10, the center-to-center deviation E
(along the sub-scanning direction) caused by the optical
axis adjustment error can be easily corrected.

25

$$AZ \leq C2,$$

$$C2 = 0.1$$

$$\ldots \quad (16)$$

According to the first embodiment, $AZ = 0.05$ and thus, the above-mentioned requirement is satisfied. However, the adjustment can be made more easily as the coefficient C2 is smaller. Accordingly, for example, it is more preferable that $C2 = 0.02$, for example. In the above-mentioned comparison example, $AZ = 0$, the above-mentioned requirement is satisfied.

Therefore, the sub-scanning direction component ΔQZ of the amount of change in the beam spot interval in each LD array 11a (11b) becomes

$$\Delta QZ = AZ \times E = 0.05 \times 54 = 2.5 \ \mu m$$

occurring in correcting the center-to-center deviation E = 54 μm caused by the optical axis deviation iZ = 0.6 (mrad). As this value is sufficiently small, the influence on an output image by the image formation apparatus using this scanning device can be controlled to be sufficiently small, and can prevent generation of an unusual/degraded image.

The following formula (17) is derived from the

formula (7):

$$\Delta QZ/\Delta\gamma =-q \times \sin \phi \times mZ \quad \ldots (17)$$

5   The absolute value of the ratio of the value of this formula (17) and the value of the formula (11) is expressed by A0, by the following formula (18):

$$A0= | (\Delta QY/\Delta\gamma)/(\Delta QZ/\Delta\gamma) |$$

10      $$= | (mY/mZ) \times \tan \phi | \quad \ldots (18)$$

This formula (18) expresses the ratio of the main scanning direction component and the sub-scanning direction component of the beam spot arrangement change occurring when the rotation γ approximately about the

15   optical axes of the light source unit 18 is made, i.e., change of the arrangement angle φ of the LD arrays 11a and 11b. The allowable range of the absolute value A0 of this ratio is shown in the following formula (19):

20

$$1/3 \le A0 \le 3 \quad \ldots (19)$$

By making the range of an absolute value A0 into the range according to the formula (19), the main

25   scanning direction component and sub-scanning direction

component of the change in the beam spot arrangement can be made to have an appropriate balance. As for this formula (18), in the case of the above-mentioned comparison example, A0 = 0, while A0 = 1.7 in the first

5   embodiment according to the present invention. Accordingly, according to the first embodiment of the present invention, the main scanning direction component and the sub-scanning direction component of the change in beam spot arrangement have an appropriate balance

10   therebetween in comparison with the comparison example.

A second embodiment of the present invention will now be described. However, for the same parts/components as those of the above-mentioned first embodiment, the same reference numerals are given, and

15   duplicated description is omitted.

FIG. 17 is a sectional view taken along the main scanning direction of a light source unit in the second embodiment of the present invention, and FIG. 18 is a sectional view taken along the sub-scanning

20   direction of the same light source. The configuration according to the second embodiment for illustrating an aspect of the present invention will now be descried with reference to FIGS. 17 and 18. As shown in FIG. 17, the light source unit 18 has a first light source part

25   18a and a second light source part 18b.

In the first light source part 18a, the LD
array 11a is fixed onto an LD base 41a, a coupling lens
12a is adhered thereonto with adjustment, and, thus,
adjustment is made on the collimate characteristics and
5   optical axis directions of laser beams emitted from the
LD array 11a according to the characteristics of
subsequent scanning optical system.   Similarly, on the
second light source part 18b, appropriate adjustment is
performed.   The first light source part 18a and second
10   light source part 18b are rotatably held onto a common
flange 42, respectively.   This light source unit 18 is
rotatably held by an optical housing 31 at an insertion
hole 32 (see FIG. 2) thereof.

By creating such a configuration, it becomes
15   possible like in the above-mentioned first embodiment to
correct a beam pitch arrangement error in the LD array
11a (11b) by rotation thereof approximately about the
optical axes of the LD array 11a (11b).   However,
according to the second embodiment, what is necessary is
20   merely to rotate each of the first light source part 18a
and second light source part 18b independently
approximately about the optical axis thereof.   Moreover,
according to the second embodiment, onto the common LD
base 41a (41b), each LD array 11a (11b) and respective
25   coupling lens 12a (12b) which make a pair are fixed.

Accordingly, when LD base 41a (41b) is rotated, there is no possibility of changing the relative positional relationship between LD array 11a (11b) and coupling lens 12a (12b).

5   Moreover, according to the second embodiment, as shown in FIG. 18, at least one of the first and second light source part 18a and 18b can be adjusted in inclination thereof along the sub-scanning direction with respect to the flange 42. By thus enabling the

10   inclination adjustment along the sub-scanning direction, the center-to-center distance in beam spots between the respective LD array 11a and 11b can be adjusted, without rotating the light source unit 18 itself approximately about the optical axes.

15   For example, when E = 54 µm in center-to-center deviation resulting from optical axis deviation of iZ = 0.6 (mrad) is corrected in the above-mentioned comparison example described with reference to FIG. 15 and FIG. 16, γ = 7.9° of rotation of the light source

20   unit 56 should be made around the optical axes, and, thereby, the beam pitch arrangement error (57.9 µm) occurs on each LD array 11a (11b).

       In contrast thereto, according to the second embodiment, for correcting E = 54 µm of center-to-center

25   deviation resulting from optical axis deviation of iZ =

0.6 (mrad), for example, the first light source part 18a should be inclined along the sub-scanning direction (in the sub-scanning section) by $\beta 1 = 4.1'$, according to the formula (2), i.e., $E = \text{fcol} \times \tan \beta 1 \times mZ$.   In this case

5   (second embodiment), no rotation of the LD array 11a (11b) alone around the optical axis occurs, and, thus, there is no possibility of change in the beam spot arrangement in each LD array 11a (11b).   In fact, as shown in FIG. 18, at least one of the LD arrays 11a and

10   11b can be inclined along the sub-scanning direction alone, as mentioned above, according to the second embodiment.

Thus, according to the second embodiment, in correction of the beam spot arrangement error caused by

15   the optical axis deviation, there is no necessity of rotating the LD array 11a (11b) with respect to the LD base 41a (41b), and, thus, the LD arrays 11a and 11b can be fixed into the LD base 41a (41b) by press-fit manner or the like.   Thus, it is possible to effectively reduce

20   the assembly costs.

As described with reference to the above-mentioned first embodiment, a scanning line interval can be adjusted in the multi-beam scanning device which uses laser beams emitted from the plurality of semiconductor

25   lasers, and scans the to-be-scanned surface.   In such a

configuration, also scanning density switching on the
to-be-scanned surface is possible accordingly as will be
described later. However, as described above, there is
a possibility that a positional deviation along the main

5   scanning direction of the beam spot sequence on each
semiconductor laser array occurs on the to-be-scanned
surface.

In other words, the semiconductor laser itself
also rotates with revolution of light source unit

10   (revolution of the semiconductor laser arrays
integrally) in the case of the type in which change of
the scanning density is made by rotating the light
source unit as a whole approximately about the optical
axes thereof. Thereby, a positional deviation along the

15   main scanning direction of the beam spot arrangement on
each semiconductor laser array occurs accordingly.
Thereby, there is a possibility that this positional
deviation along the main scanning direction may bring
about quality degradation in the output image from the

20   image output apparatus.

Instead, in an image formation apparatus
disclosed by Japanese laid-open patent application No.
2000-255097, an adjustment member is provided which can
adjust an imaging position (sub-scanning direction) on a

25   light path between a semiconductor laser array and a

beam combining part, equipped with a light source unit which combines laser beams emitted from a plurality of semiconductor laser arrays. In this configuration, a special mechanism by which the adjustment member is

5   driven is needed and thus, there is a possibility of causing enlargement of the apparatus, the cost may rise, and also, the reliability may be lowered.

According to another aspect of the present invention, these problem are directed to be solved in

10   connection with a case where the scan line density is easily switched in a multi-beam scanning device.

A third embodiment of the present invention devised for this purpose will now be described.

As the third embodiment, a $2n$ beam scanning

15   device employing laser beams from two semiconductor laser arrays (LD arrays) each of which has n light-emitting points located in a line so as to form a shape of an array with equal intervals (q) will now be described for a case $n = 4$, as in the above-mentioned

20   first embodiment.

In the description below, 111a, 111b denote semiconductor laser arrays (LD array); 112a, 112b denote coupling lenses; 113 denotes cylindrical lens, 114 denotes a polygon mirror; 115 denotes a scanning optical

25   system; 116 denotes a photoconductor drum (providing a

to-be-scanned surface); 117 denotes a beam combining prism; 118 denotes a light source device (light-source unit); 119 denotes a part of detecting synchronization signals; a1 through a4 denote beam spots from the LD array 111a formed on the to-be-scanned surface 116; b1 through b4 denotes beam spots from the LD array 111b formed on the to-be-scanned surface; Ca and Cb denote the center positions of the beam spots from the LD arrays 111a and 111b, respectively; QY, QZ denote the interval between beam spots on the same LD array on the to-be-scanned surface 116; PY, PZ denote the interval (center-to-center pitch) between the center positions Ca and Cb; and subscripts Y, Z denote the main and sub-scanning directions, respectively.

Moreover, q denotes light-emitting point interval on the LD array; n denotes the number of light-emitting points on each LD array; ϕ denotes arrangement (inclination) angle from the sub-scanning direction; fcol denotes the focal length of each coupling lens; θ denotes half the angle at which the laser beams emitted from the two LD arrays cross near a deflection reflective surface of the polygon mirror between these LD arrays; $\Delta\phi$, γ denote rotation angle approximately about the optical axes.

In FIG. 19, laser beams emitted from the first

LD array 111a and second LD array 111b are coupled by the corresponding coupling lenses 112a and 112b, respectively, and are shaped by apertures not shown. These parts, i.e., the above-mentioned LD arrays 111a

5   and 111b, the coupling lenses 112a and 112b, and a holding member holding them are called a light source device 118. Positional adjustment (positional relationship adjustment) of the LD arrays 111a and 111b and the coupling lenses 112a and 112b is performed so

10   that desired collimate characteristics and desired light-emitting ejection direction (optical-axis direction) may be provided.

In FIG. 19, illustration is omitted for the above-mentioned holding member of the LD arrays 111a and

15   111b. FIG. 20A shows one example of the same disclosed by Japanese laid-open patent application No. 2001-4941, and is a perspective view showing a light source device configuration in a multi-beam scanning device which uses two general-purpose semiconductor lasers as light

20   sources, which can also be employed in the above-mentioned third embodiment of the present invention.

In the figure, the two semiconductor lasers 1101 and 1102 are press-fitted into fitting holes formed in a rear surface of an aluminum-die-cast base member

25   1103 with an interval of 8 mm therebetween (enabling

parallel provision of coupling lenses). The coupling

lenses 1104 and 1105 are fixed in a gap between the

semiconductor lasers 1101, 1102 and an accompanying U-

shaped support part 1103b with ultraviolet setting resin,

5   after the X positions thereof are adjusted so that the

laser beams emitted from the semiconductor lasers 1101

and 1102 may have desired divergent characteristics and

Y, Z positions are adjusted so that they may have

predetermined beam emitting directions. The

10   semiconductor lasers 1101, 1102, base member 1103 and

coupling lenses 1104, 1105 form a light-source device.

The base member 1103 is fixed onto a holding

member 1107 by screw, a cylindrical outer surface 1107a

(the center of which is coincident with the center C of

15   the optical axes of the light source device) thereof is

fitted into a fitting hole 1109a of a side wall 1109 of

an optical housing, and, thus, positioning is made.

Then, the base member 1103 is pressed by a spring 1110

onto the side wall 1109 as a result of a ring-shaped

20   pressing member 1111 being engaged by a flange part

1107b. Further, a standing and bending part 1110a of

the spring 1110 is engaged with a hole 1111a of the

pressing member 1111, an arm 1110b at the opposite end

thereof is engaged with a projection 1109b of the side

25   wall 1109, and, thus, clockwise twisting force is

generated. Thereby, a rotation-stopping part 1107c of the holding member 1107 is made be pressed onto an adjusting screw 1112. Then, by the adjusting screw 1112, the rotation adjustment approximately about the optical

5 axes is made possible. Such a rotation approximately about the optical axes is called 'γ rotation' as mentioned above. The adjustment screw 1112 is held by a thread formed in the side wall 1109.

FIG. 20B shows an exploded perspective view of

10 a mechanism for performing the γ rotation of the light source device shown in FIG. 20A also disclosed by Japanese laid-open patent application No. 2001-4941. As shown in the figure, the mechanism rotates the light-source device 1211 with respect to the housing 1212 of

15 the multi-beam scanning device, and, includes a sliding member 1213, a motor bracket 1214, the pressing plate 1215, the spring 1218, the sprint pressing plate 1219, a stepper motor 1220, guides 1221 and a switch 1226.

As in the above-described structure shown in

20 FIGS. 20A and 20B, in the third embodiment of the present invention, the LD arrays 111a and 111b are fixed to the holding member by a press-fit manner. However, instead, the same may be fixed by another method, for example, a method of using a pressing plate together

25 with fixing screws. Further, the coupling lenses 112a

and 112b are fixed onto a U-shaped projection provided

on the holding member by using ultraviolet setting

adhesive or the like. However, instead, for example,

the coupling lenses 112a and 112b may be fixed inside of

5   a lens cell having a male thread, and this is screwed

into a female thread part provide in the holding member,

for example.

The two LD arrays 111a and 111b fixed and held

as mentioned above are disposed away from one another

10   along the main scanning direction, and the laser beams

having undergone the coupling functions of the coupling

lenses 112a and 112b (namely, optical axes of the

respective two LD arrays 111a and 111b) cross mutually

near the deflection reflective surface of the polygon

15   mirror 114. By configuring as described above, it

becomes possible to reduce the deviation in optical

characteristics of the beam spots on the to-be-scanned

surface 116 from both the LD arrays 111a and 111b. The

crossing angle is set as 2θ.

20   The eight laser beams emitted from the light

source device 118 are imaged along the main scanning

direction as long images along the sub-scanning

direction on the deflection reflective surface of the

polygon mirror 114 by the function of the cylindrical

25   lens 113, and after the deflection/reflection is carried

out, the scanning optical system 115 causes the laser
beams to scan the to-be-scanned surface 116
(photoconductor drum) at a uniform velocity. In the
light source device 118, the above-mentioned angle 2θ

5   can be made smaller by configuring, as shown in FIG. 21,
i.e., to employ a beam combining prism 117. Thereby,
the deviation in optical characteristics of the beam
spots on the to-be-scanned surface 1167 from both the LD
arrays 111a and 111b can be further reduced.

10   The LD arrays 111a and 111b (light-emitting
point interval: q) are disposed with inclination angle
(arrangement angle) ϕ with respect to the sub-scanning
direction as shown in FIG. 22A. In this case, on the
to-be-scanned surface 116, through magnification

15   function of the optical system (mY on the main scanning
direction; mZ on the sub-scanning direction), as shown
in FIG. 22B, the interval (QY, QZ) between adjacent beam
spots is expressed as follows:

20       $QY = q \times \sin \phi \times mY$

           $QZ = q \times \cos \phi \times mZ$

Therefore, the interval (RY, RZ) of the farthest beam
spots on each LD array is expressed as follows:

25

$$RY = (n-1) \; QY = (n-1) \times q \times \sin \phi \times mY$$

$$RZ = (n-1) \; QZ = (n-1) \times q \times \cos \phi \times mZ$$

Generally speaking, it is difficult to change
the magnification (and focal length) of a scanning
optical system in case a multi-beam scanning device
employs an existing scanning optical system (the optical
system subsequent to the deflector is used as it is).
However, desired magnification (mY and mZ) can be
obtained by setting appropriately the focal length of an
optical system (i.e., coupling lens and cylindrical
lens) before the deflector relatively easier.

FIGS. 23A and 23B illustrate methods of
placing beam spots on the to-be-scanned surface 116.

FIG. 23A shows a way of arranging alternately
the beam spots of first LD array 111a, and the beam
spots of the second LD array 111b. The sub-scanning
direction component PZ of the distance (referred to as a
center-to-center distance) between the central positions
Ca and Cb of the beam spot arrangement of the first LD
array 111a and second LD array 111b corresponds to one
scanning line interval (d). Thus, the center-to-center
distance at a time of 1200 dpi is set as $P1200 = d$.

FIG. 23B shows a way of arranging the beam
spots of the first LD array 111a, and the beam spots of

the second LD array 111b, in series. The sub-scanning

direction component PZ of the center-to-center distance

between centers Ca and Cb of the respective beam spot

arrangements of the LD arrays 111a and 111b corresponds

5   to $2n \cdot d$.

Further, in the multi-beam scanning device of

the third embodiment, the detection part 119 for

detecting the synchronized signals for determining

scanning start timing is provided. Then, for each of

10   the LD arrays 111a and 111b, the above-mentioned

synchronization signal is obtained from the laser beam

emitted from one light-emitting point, and from the

synchronized signal obtained from the laser beam from

the one light-emitting point, the scanning start timing

15   of the laser beams from the other light-emitting points

are determined as being delay by specific times (delay

times), in sequence. Thereby, it is possible to make

scans with the respective laser beams starting from the

same position (along the main scanning direction).

20   As mentioned above, the laser beams emitted

from the LD arrays 111a and 111b cross near the

deflection reflective surface of the polygon mirror 114

at the crossing angle 2θ. Accordingly, by rotating the

light source device 118 configured as shown in FIG. 20A,

25   about a rotational axis parallel to the optical axes of

these laser beams according to the manner of γ rotation

mentioned above, an optical axis shift along the sub-

scanning direction of the laser beams which come out of

the two LD arrays 111a and 111b is obtained, and,

5   consequently, the sub-scanning direction component PZ of

the above-mentioned center-to-center distance between

the two central positions Ca and Cb of the beam spots on

the to-be-scanned surface 116 can be appropriately

adjusted.   That is, the beam spot arrangement of FIG.

10   23A can be switched into that shown in FIG. 23B, and

scanning density can thus be switched.

In the case of the example shown in the

figures, switching between 1200 dpi and 600 dpi can be

performed.   In fact, in FIG. 23A, the interval between

15   adjacent scanning lines is d = 21.2 μm (scanning density

is 1200dpi), while the interval between adjacent

scanning lines is 2d = 42.3 μm (scanning density is

600dpi) in FIG. 23B.

It is noted that, through the γ rotation of

20   the light source device 118, the two LD arrays 111a and

111b are revolved as shown in FIGS. 23A and 23B, while

each of the two LD arrays 111a and 111b rotates actually

(although not clearly expressed in the figures).

Therefore, as shown in FIG. 24, the beam spot

25   arrangement (intervals along the sub-scanning direction

(RZ) and main scanning direction (RY)) on the to-be-scanned surface 116 on each LD array is changed from the initial state.

When the amount or angle of γ rotation of the light source device 118 is assumed as $\Delta\phi$, the amount of change in the beam spot arrangement on the to-be-scanned surface 116 (the amount of change: ΔRY; the amount of change: ΔRZ, in the interval along the sub-scanning direction and the interval along the main scanning direction, respectively) will now be calculated. First, the center-to-center distance P along the sub-scanning direction shown in FIGS. 23A, 23B is expressed by

$$P = 2 \times fcol \times \tan\theta \times \sin\gamma \times mZ \quad \cdots (20)$$

Then, this formula (20) is differentiated with respect to ϕ (as $\Delta\phi = \Delta\gamma$),

$$\Delta P/\Delta\phi = 2 \times fcol \times \tan\theta \times \cos\gamma \times mZ \quad \cdots (21)$$

Now, $\gamma \approx 0$. Then, it is assumed $\cos\gamma = 1$. Accordingly, from the formula (21),

$$\Delta\phi = \Delta P/(2 \times fcol \times \tan\theta \times mZ) \quad \cdots (22)$$

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Further,

$$\Delta P = P_{600} - P_{1200}$$
$$= 2n \cdot d - d = (2n-1) \cdot d \quad \cdot \cdot \cdot (23)$$

5

Accordingly, by substituting the formula (23) for the formula (22),

$$\Delta \phi = (2n - 1) \cdot d/(2 \times fcol \times \tan \theta \times mZ)$$

10
$$= \{(2n-1)/2\} \times \{d/(fcol \times \tan \theta \times mZ)\} \quad \cdot \cdot \cdot (24)$$

Then, as mentioned above,

$$RY = (n-1) \times q \times \sin \phi \times mY$$

15

and this formula is differentiated with respect to ϕ, then, the absolute value thereof is obtained, i.e.,

$$\Delta RY = |(n-1) \times q \times \cos \phi \times mY \times \Delta \phi| \quad \cdot \cdot \cdot (25)$$

20

Then, the formula (24) is substituted for the formula (25), thus,

$$\Delta RY = |(n-1) \times q \times \cos \phi \times mY \times \{(2n-1)/2\} \times$$
25 $$\{d/(fcol \times \tan \theta \times mZ)\}|$$

$$= \left| (n-1) \times (2n-1)/2 \right\} \times$$

$$\{ (q \times \cos \phi \times mY \times d)/(fcol \times \tan \theta \times mZ) \} \; \Big|$$

Similarly,

5       $RZ = (n-1) \times q \times \cos \phi \times mY$

is differentiated with respect to ϕ, the absolute value

thereof is obtained, and then

$$\Delta RZ = \left| (n-1) \times q \times \sin \phi \times mY \times \Delta \phi \right|$$

10

Thus, the formula (24) is substituted therefor, and,

thus,

$$\Delta \phi = \{ (2n-1)/2 \} \times \{ d/(fcol \times \tan \theta \times mZ) \}$$

15

$$\Delta RY = \Big| \{ (n-1) \times (2n-1)/2 \} \times$$

$$\{ (q \times \cos \phi \times mY \times d)/(fcol \times \tan \theta \times mZ) \} \; \Big|$$

$$\Delta RZ = \Big| \{ (n-1) \times (2n-1)/2 \} \times$$

20       $$\{ (q \times \sin \phi \times d)/(fcol \times \tan \theta) \} \Big|$$

In FIG. 24,

$$QY' = QY + \Delta QY$$

25       $$RY' = RY + \Delta RY$$

$$QZ' = QZ - \Delta QZ$$

$$RZ' = RZ - \Delta RZ.$$

Assuming the specification of the above-mentioned third embodiment as shown in FIG. 25,

$$\Delta\phi = 0.7(^{\circ})$$

$$\Delta RY = 2.8 (\mu m)$$

$$\Delta RZ = 4.5 \ (\mu m)$$

Then, assuming that the multi-beam scanning device in the third embodiment is used as a multi-beam scanning device in an image formation apparatus using an electronic photograph process, it is assumed that permissible value of change amount in the beam spot arrangement (in case of scanning density switching) as 1/4 the scanning line interval (= d/4). Then,

$$d/4 = 5.3 \ (\mu m)$$

Thus, for the main scanning direction (ΔRY) and for the sub-scanning direction (ΔRZ), the above-mentioned change amount on the beam spot arrangement falls within the permissible range. Accordingly, by satisfying the following requirements:

$$\Delta RY = \left| \{(n-1) \times (2n-1)/2\} \times \right.$$

$$\left. \{(q \times \cos \phi \times mY \times d)/(fcol \times \tan \theta \times mZ)\} \right| \leq d/4$$

$$\cdots \quad (I)$$

5 $$\Delta RZ = \left| (n-1) \times (2n-1)/2\} \times \right.$$

$$\left. \{(q \times \sin \phi \times d)/(fcol \times \tan \theta)\} \right| = d/4$$

$$\cdots \quad (II)$$

an output image by the image formation apparatus which

10 uses the multi-beam scanning device in which the above

conditional formulas (I) and (II) are satisfied can be a

quality image.

As the right side of the above-mentioned

conditional formulas (I) and (II) have smaller values,

15 higher quality image can be obtained. However, it is

also possible that a value of d/2 or less may be used

instead of d/4, depending on particular requirements of

required image quality, development, transfer and fixing

conditions, and so forth.

20 Moreover, in a scanning density switching, the

multi-beam scanning device which may preferably set up

the delay time such that the scanning start position on

each beam spot may be the same on the to-be-scanned

surface 116 when the higher (scanning line interval is

25 smaller) scanning density is applied/selected. Thus, a

configuration is made such that the predetermined beam

spot arrangement is properly obtained in the higher

scanning density mode (1200dpi), and, the above-

mentioned amount of change (ΔRY, Δ RZ) occurs in the

5   lower scanning density mode (600dpi). As a result, in

the higher scanning density mode in which higher-quality

output image is obtained and thus the influence of the

beam spot arrangement error has more remarkable on the

output image, more precise beam spot arrangement, i.e.,

10   having less error, in both the main and sub-scanning

directions, can be obtained.

According to the specification shown in FIG.

25, the main scanning direction component of the beam

spot arrangement on each LD array is such that

15

$$QY = q \times \sin(\phi) \times mY = 0.197 \ (mm)$$

And, thus, as this distance is very small, the

synchronization signal may not be able to be

20   individually detected for each of the four laser beams

on each LD array depending on the scanning speed.

Therefore, it may be that, the synchronization signal is

detected only for one light-emitting point of the four

as mentioned above, a specific time (delay time) is

25   shifted from the synchronization signal in sequence for

the other respective light-emitting points for setting
up the scanning start timing therefor. On the other
hand, the main scanning direction component PY of the
center-to-center distance between the center positions
Ca and Cb of the beam spot arrangements between the two
LD arrays 111a and 111b is expressed as:

$$PY = FY \times (2\theta) = 225 \times (5° \times 2\pi/360°) = 19.6 \ (mm)$$

Thereby, as this value is relatively large, it is easy
to detect the synchronization signals for the both LD
arrays, respectively.

A fourth embodiment of the present invention
will now be described.

As a configuration of the fourth embodiment, a
case where the specification shown in FIG. 26 is applied
in the above-described third embodiment is discussed.

According to the fourth embodiment, the
required rotation amount $\Delta\phi$ of the light source device
118 for switching of the scanning line density, change
amount in the beam spot arrangement on the to-be-scanned
surface 116 (ΔRY on the main scanning direction; ΔRZ on
the sub-scanning direction) occurring due to the above-
mentioned rotation of $\Delta\phi$ are as follows:

$$\Delta\phi = 3.6(^\circ)$$

$$\Delta RY = 39.3 \ (\mu m)$$

$$\Delta RZ = 0.3 \ (\mu m)$$

5 Thus, the main scanning direction component $\Delta RY = 39.3$ μm of the amount of change in the beam spot arrangement exceeds the above-mentioned permissible amount $d/4 = 5.3$ μm. On the other hand, as to the sub-scanning direction, no problem occurs as $\Delta RZ = 0.3$ μm is sufficiently 10 smaller than the above-mentioned permissible value 5.3 μm.

Even in such a case, the scanning start position (along the main scanning direction) on each laser beam can be made uniform as a result of the delay 15 time applied there being suitably set according to the switching of scanning density. The delay times for both the scanning densities (1200dpi and 600dpi) can be calculated in a design manner.

For example, assuming that the delay time 20 applied to the higher scanning density mode (at the time of 1200dpi) is T1200, while the delay time applied to the lower scanning density mode (at the time of 600dpi) is T600, and the scanning speed is Vs, the amount of change ΔT in delay time to be applied at the time of a 25 scanning density switching can be obtained as

$$\Delta T = T600 - T1200 = \Delta QY/Vs.$$

Since

$$\Delta QY = \Delta RY/(n-1) = 39.3/(4-1) = 13.1 \ (\mu m)$$

5

In case Vs=500 (m/s), for example,

$$\Delta T = 26.2 \ (ns)$$

10   Moreover, by providing a measure of detecting
at least the main scanning direction component of the
spot interval in the beam spot arrangement, it becomes
possible to determine the delay time to be applied more
precisely according to the detection result.

15   Furthermore, when this multi-beam scanning
device is used as a multi-beam scanning device in an
image formation apparatus applying an electronic
photographic process, a function such that a beam spot
arrangement detection pattern can be obtained as an

20   output image thereof may be provided. Then, an operator,
such as a user or a service person, may determine the
delay time to be applied before and after the scanning
density switching operation by observing the above-
mentioned beam spot arrangement detection pattern. Then,

25   the thus-determined delay time to be applied may be

input through an operation panel prepared in the main part of the machine.

In an image formation apparatus, such as a digital color copying machine or a color printer, a so-called tandem type one, in which a plurality of photoconductor drums, 1K, 1C, 1M, and 1Y are arranged corresponding to respective color components (for example, black: K, cyan: C, magenta: M, and yellow: Y) in series along a direction along which an image recording medium (for example, paper) is conveyed is adopted in cases. In such a case, as shown in FIG. 27A, separate scanning devices (110K, 110C, 110M, 110Y) may be provided for the respective color components, or, alternatively, a common scanning device 110A may be provided as shown in FIG. 27B. Furthermore, it is also possible that, as shown in FIGS. 27C and 27D, two scanning devices 110A1, 110A2, or 110B1 and 110B2 may be provided. In such a configuration, it is possible to provide output images at a rate 4 times, as compared with a case where only a single photoconductor drum is used (in case of four color components, four times of writing operation should be made for each image formation). For more details on such a tandem-type machine, see United States patent application S.N. 09/956,900, filed on September 21, 2001, by the same

applicant, in particular, FIGS. 1-10 and associated description, the entire contents of which are hereby incorporated by reference.

In case a single beam comes out of each of the
5   scanning devices 110K, 110C, 110M, and 110Y corresponding to the respective color components, a full color (four color components) image can be obtained by the image output apparatus which uses these scanning devices. In contrast thereto, a case is assumed in
10   which at least one of the four scanning devices (for example, the scanning device for black component 110k) is of a four-beam multi-beam scanning device according to any of the above-mentioned embodiments of the present invention, and image formation is performed by using
15   only this multi-beam scanning device in case. In this case, as compared with the above-mentioned case of obtaining a full color image, 4 times as high-density printing can be obtained. Alternatively, when the conveyance speed on a recording medium (and process
20   speed) is increased 4 times, it becomes possible to increase image output number of sheets by 4 times.

Moreover, high resolution is required in many cases only for black component for obtaining a character/letter image part even at a case of obtaining
25   a full color image as a whole. Accordingly, in addition

to the above 4-beam multi-beam scanning device 110K

(black), simultaneously the other single-beam scanning

devices (110C, 110M, 110Y) are operated, and, thus, it

becomes possible to obtain a high-definition output

5   image effectively also for an image in which

character/photograph/line drawing image parts are

combined.

Various modification is possible for the

present invention within a basic concept thereof, which

10 are not limited to the above-mentioned embodiments. For

example, although the present invention is applied to

the color laser printer according to the embodiments, a

multi-beam scanning device according to the present

invention can also be applied as a laser writing optical

15 system in an image formation apparatuses, such as a

digital copier or a combined/composite machine including

the functions of various apparatuses.

Further, the present invention is not limited

to the above-described embodiments, and variations and

20 modifications may be made without departing from the

scope of the present invention.

The present application is based on Japanese

priority applications. Nos. 2001-062928 and 2001-202309,

filed on March 7, 2001 and July 3, 2001, respectively,

25 the entire contents of which are hereby incorporated by

reference.